



International Symposium  
Qualification of dynamic analyses of dams and their equipments  
and of probabilistic seismic hazard assessment in Europe  
31th August – 2nd September 2016 – Saint-Malo

AFPS Working Group  
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Session 1: Qualification of Probabilistic Seismic Hazard Assessment

# Discussing SHARE PSHA results for France



Saint-Malo © Yannick LE GAL

# SUMMARY

## 1.CONTEXT

- The SHARE project
- Comparison with seismic zonation map for France
- The scope

## 2.ANALYSIS OF SHARE MODEL HYPOTHESIS

- SHARE logic tree
  - On GMPEs
  - On source models
  - On zonation
  - On activity parameters
  - On  $M_{\max}$

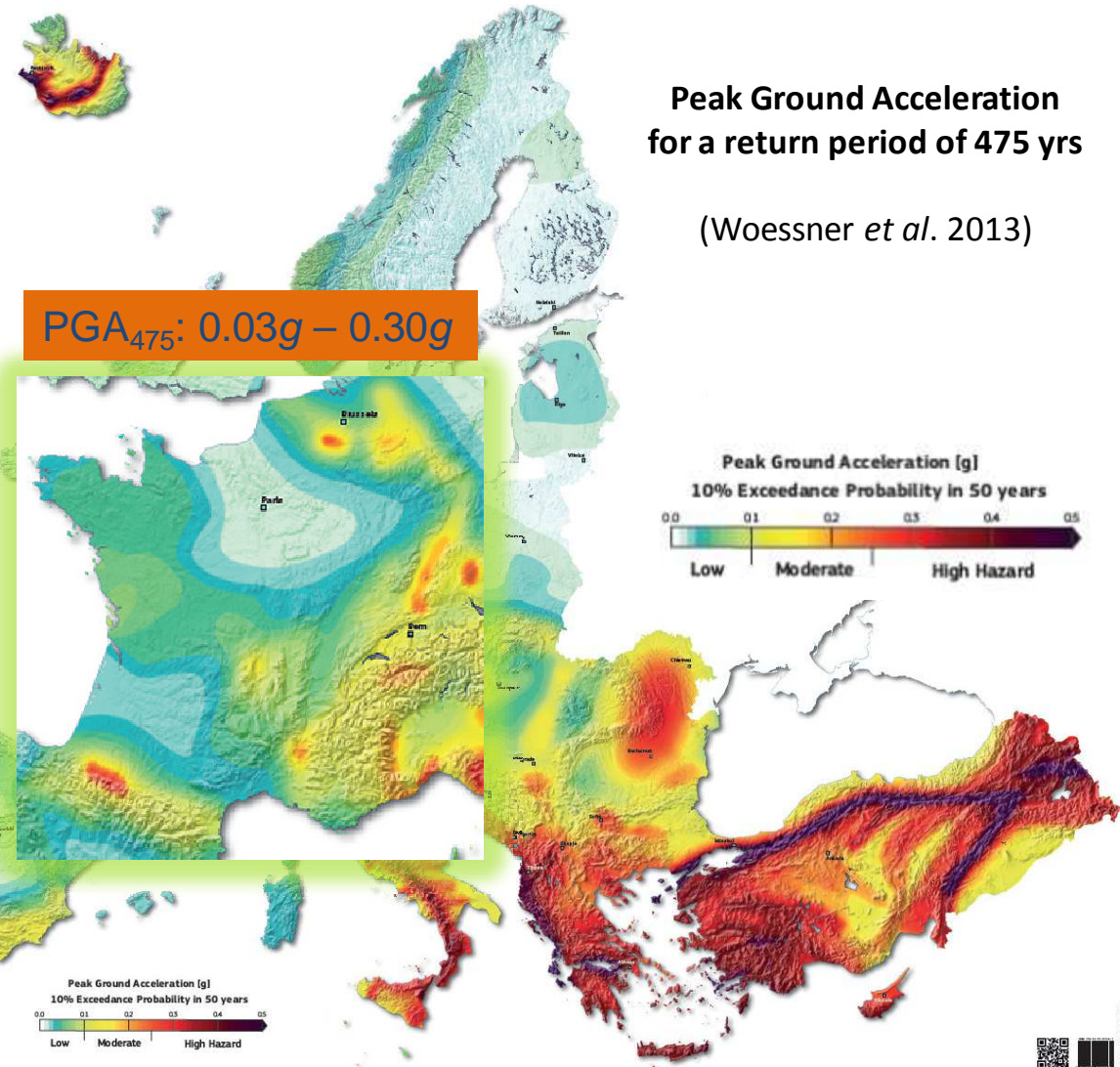
## 3.SENSITIVITY STUDY

- On  $M_{\max}$  and  $M_{\min}$
- Uncertainty on earthquake recurrence

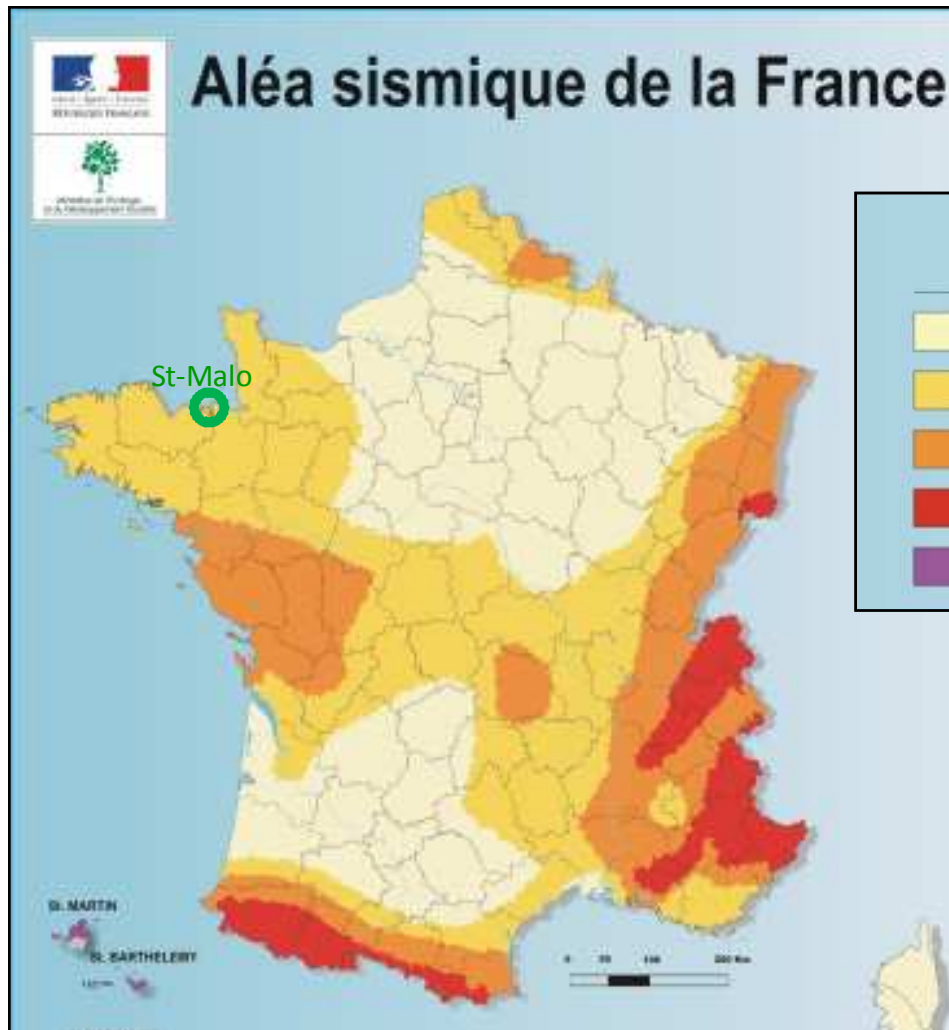
# SHARE project (2009-2013)

- **Time-independant hazard model for Europe**
  - for return periods 73 to 4975 years
  - for spectral periods up to 4s
- **Reference model for the revision of the EC for seismic design of building**
- **Software OpenQuake (GEM)**
- **Documentation**
  - Deliverables, Shapefiles, Input files ([www.efehr.org](http://www.efehr.org))






(Many key information missing)



# Regulatory seismic zonation



(National Decrees No. 2010-1254 and 2010-1255)

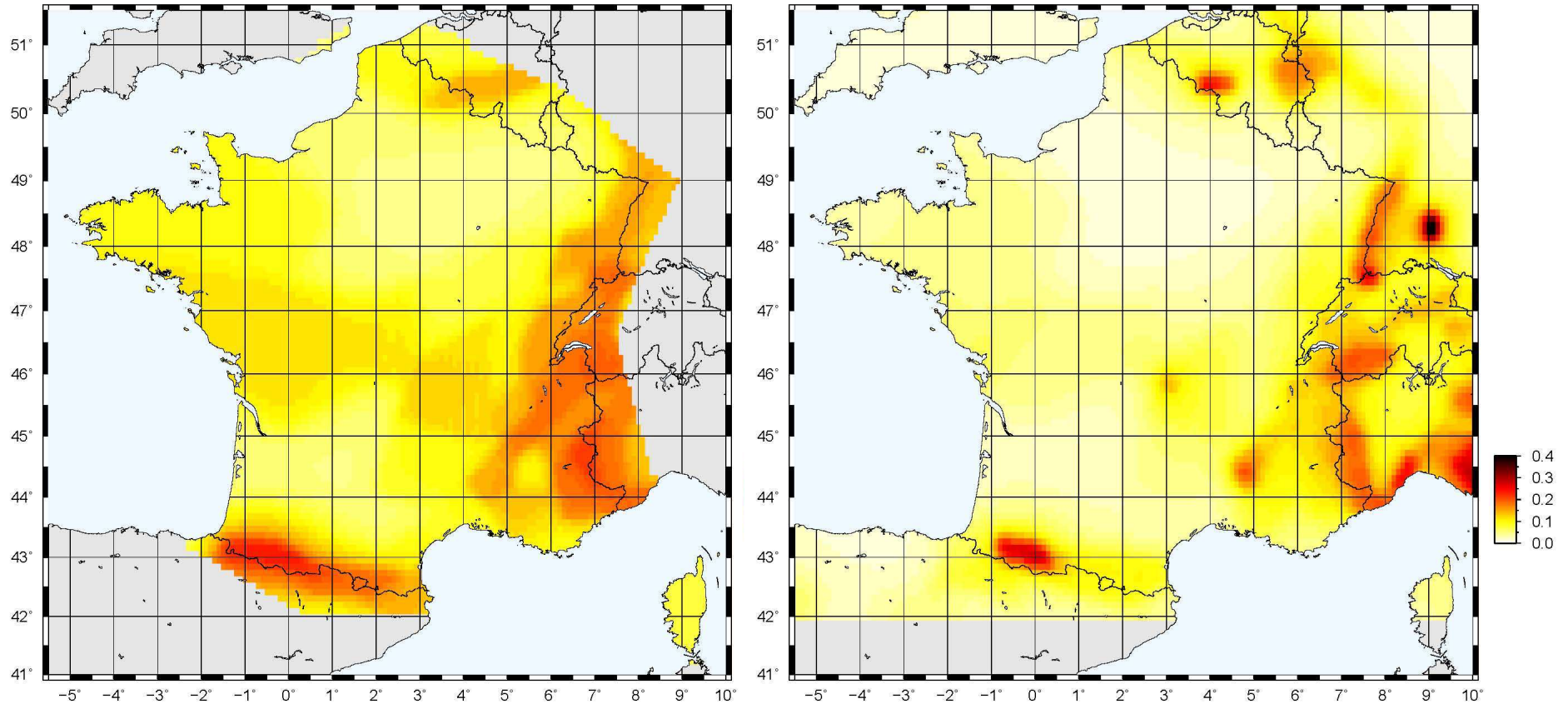
Aléa	Mouvement du sol
 très faible	accélération $< 0.7 \text{ m/s}^2$
 faible	$0.7 \text{ m/s}^2 \leq \text{accélération} < 1.1 \text{ m/s}^2$
 modéré	$1.1 \text{ m/s}^2 \leq \text{accélération} < 1.6 \text{ m/s}^2$
 moyen	$1.6 \text{ m/s}^2 \leq \text{accélération} < 3.0 \text{ m/s}^2$
 fort	accélération $\geq 3.0 \text{ m/s}^2$

- Parts of the Alps and Pyrenees are classified in “medium” hazard level
  - + Guadeloupe, Martinique

# PSHA maps: $PGA_{475\text{ yrs}}$

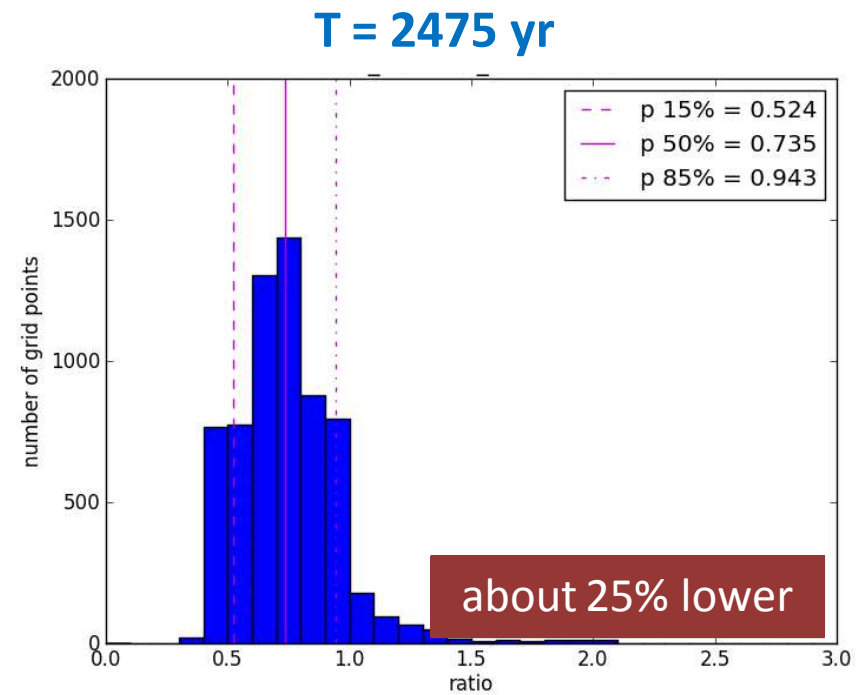
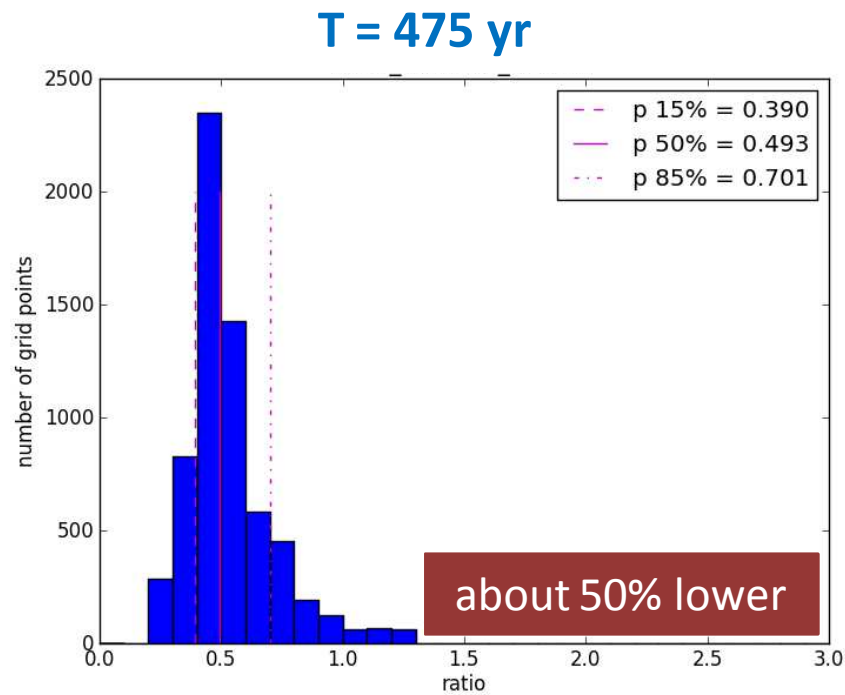
MEDD (2002)

SHARE (2013)



The hazard calculated in SHARE is generally lower than the hazard from the 2002 study.

# ratios $PGA_{475} \frac{SHARE}{MEDD(2002)}$



The hazard calculated in SHARE is generally lower than the hazard from the 2002 study.

# The scope

- Identify, understand and analyse the assumptions, methods and final decisions, that produced the SHARE PSHA results in France.
- Quantify some uncertainties on the seismic source model that SHARE did not take into account

Within the framework of an **AFPS Working Group** for SHARE results in France

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  - On zonation
  - On activity parameters
  - On  $M_{\max}$

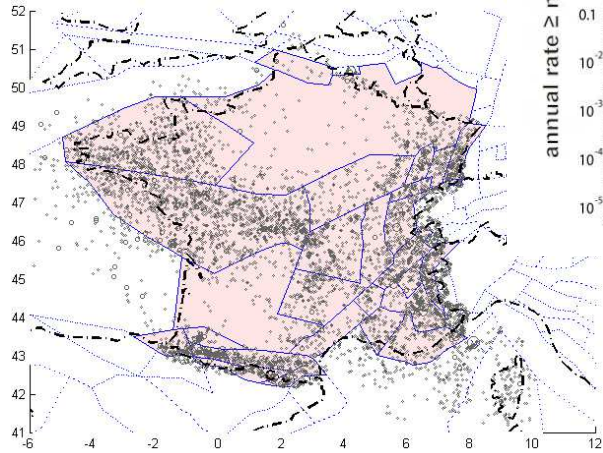
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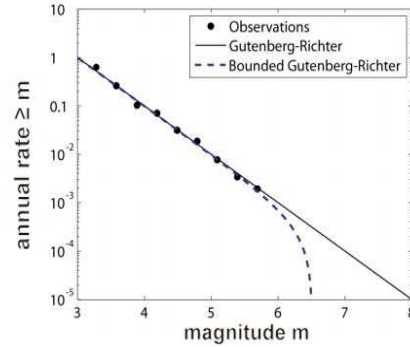


# PSHA

## 1) Source model



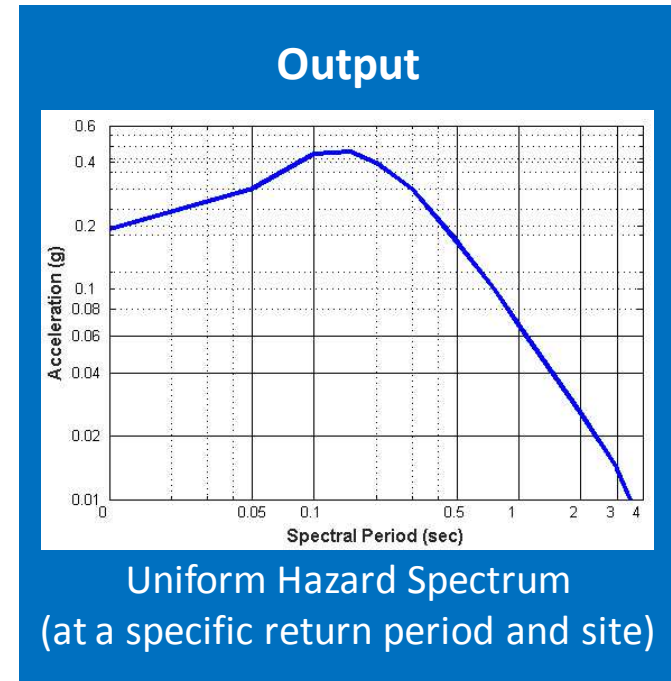
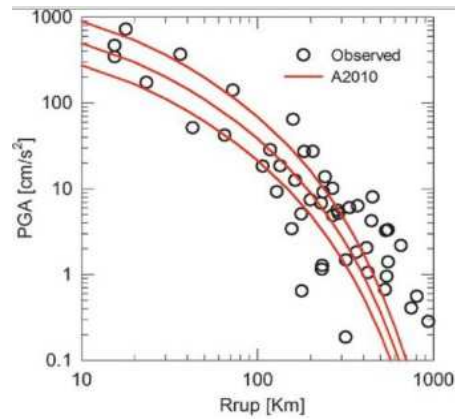
Probability of EQ occurrence (G-R curves)



Characterisation of seismic activity: *a* and *b*

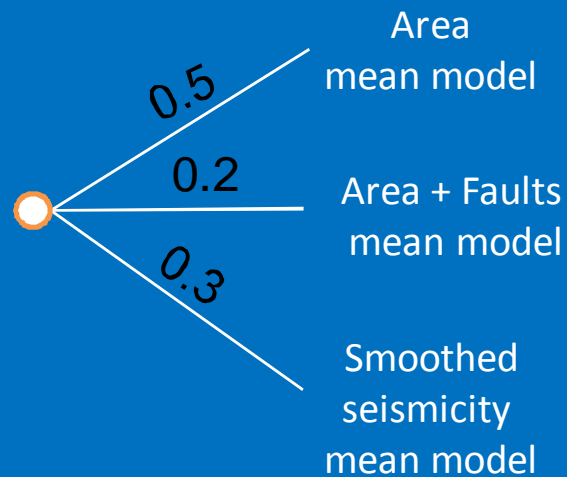
## 2) Ground motion prediction model

Probability of ground motion occurrence



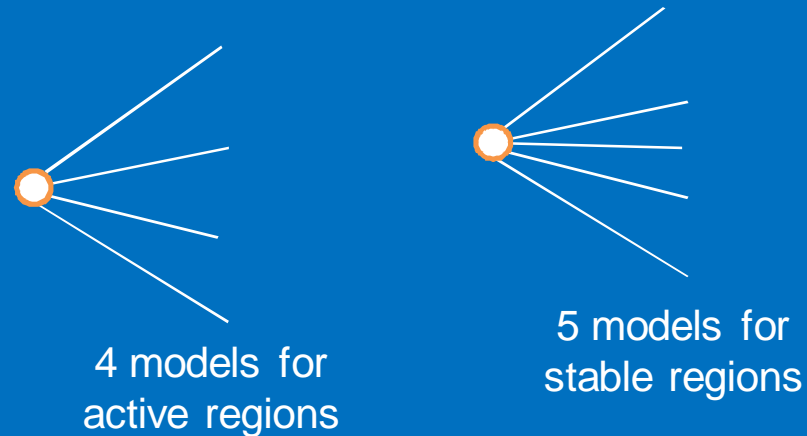
# SHARE logic tree - epistemic uncertainties

## Source models



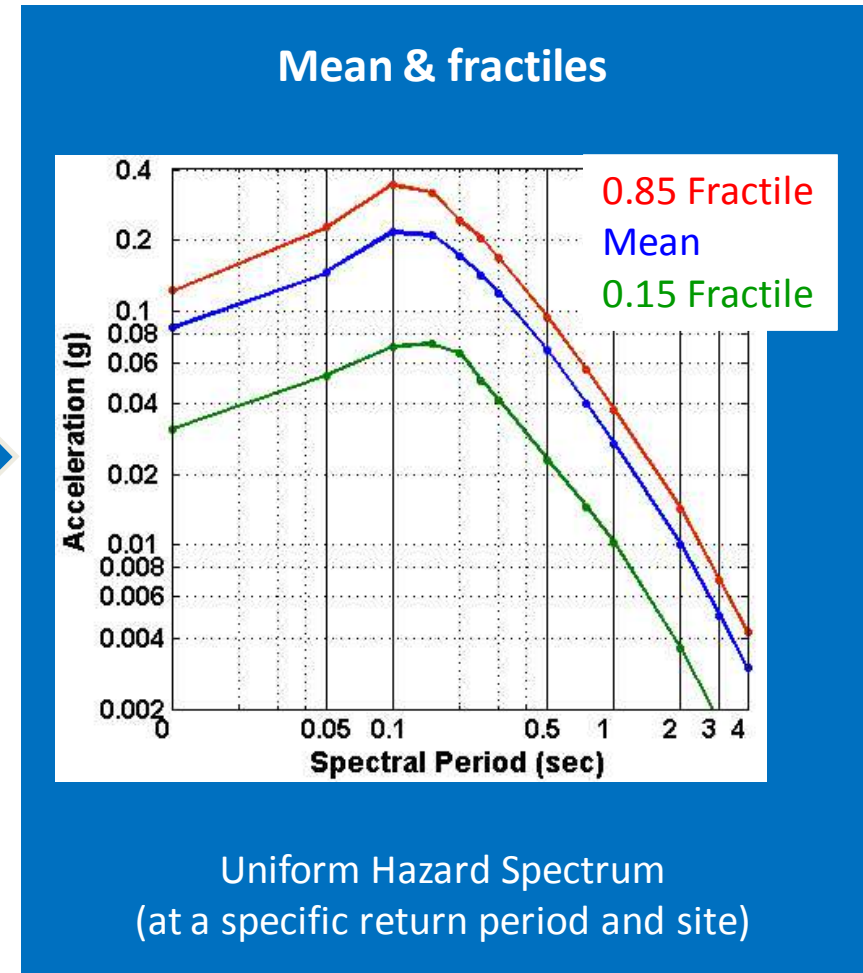
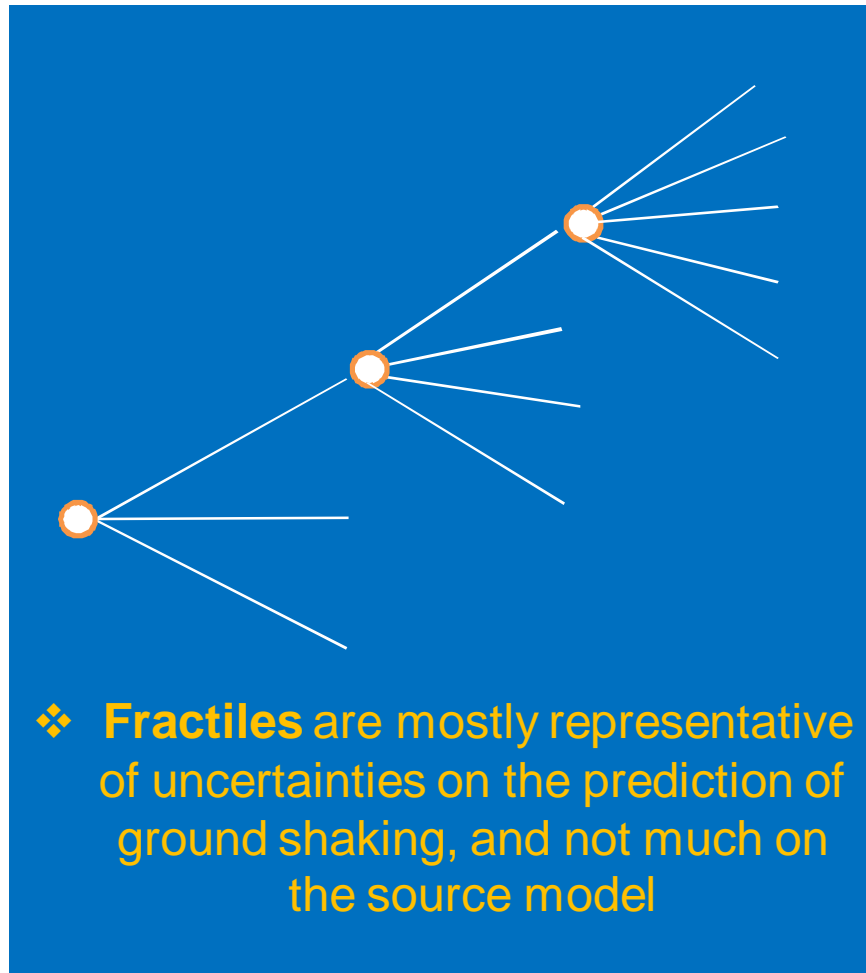
- ❖ No uncertainty propagated on these mean models (as for ex.  $a$ ,  $b$ ,  $M_{max}$ ,  $h$ )

## Ground motion prediction models



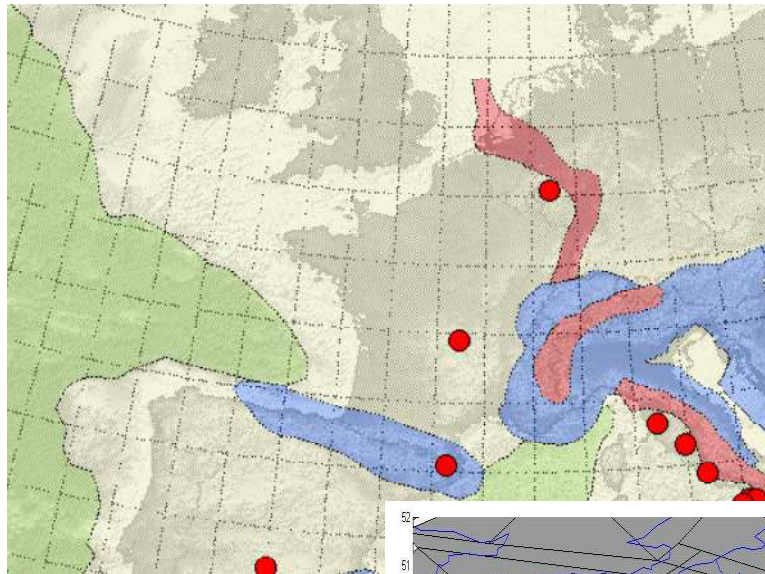
- ❖ Uncertainty extensively taken into account and propagated in a complete way

# Output of SHARE logic tree

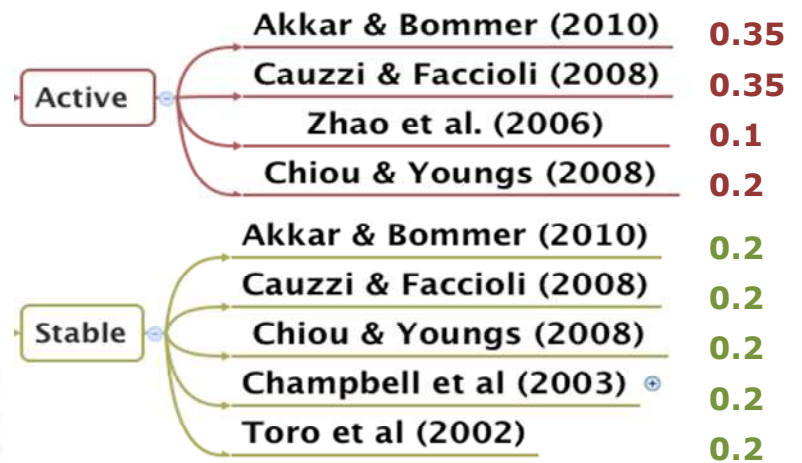


# Hypothesis on GMPEs

The whole Europe was divided into 6 major tectonic “superzones”

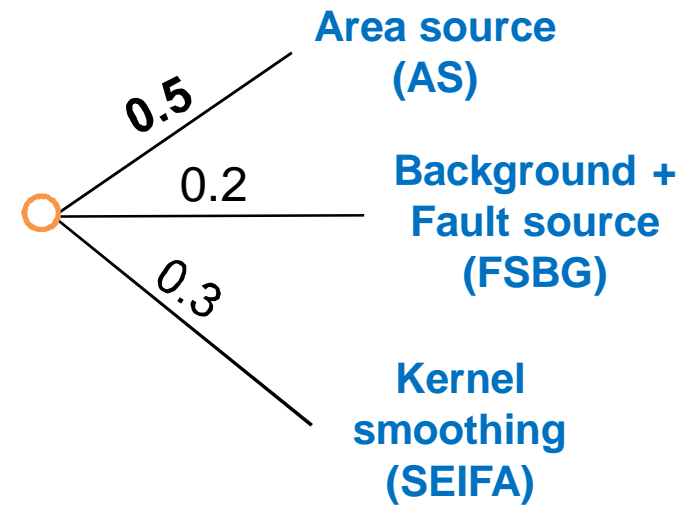
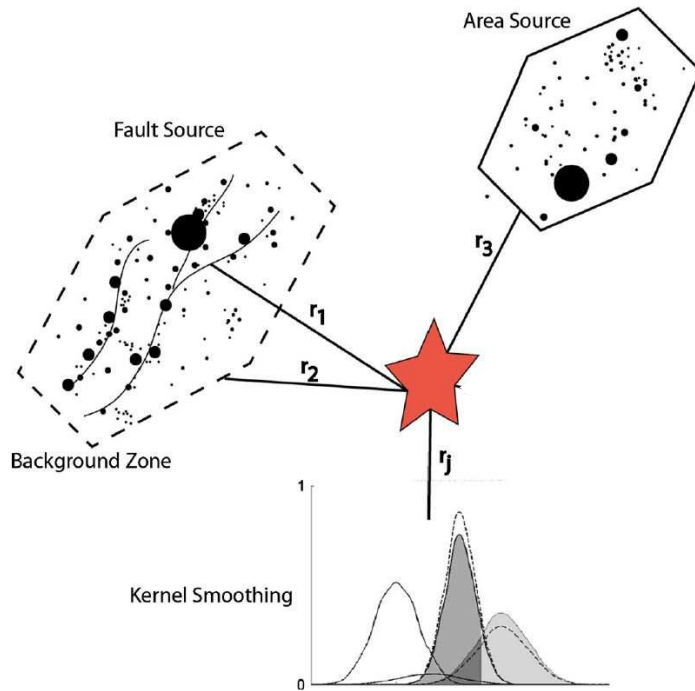


Beige: SCR continental crust; blue: stable areas; burgundy: ASCR extensional crust; red circle: active volcanoes

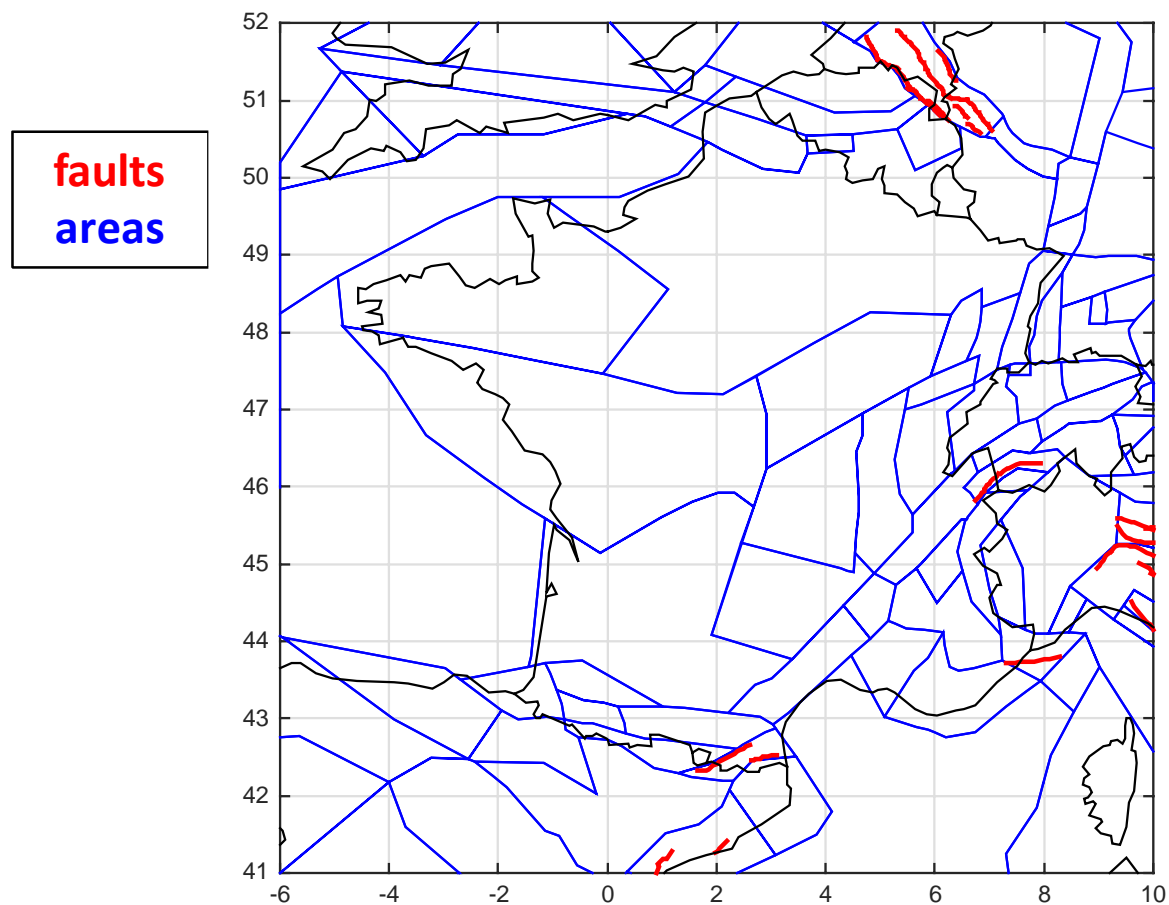


Delavaud *et al.* (2012)

# Hypothesis on source model



# Hypothesis on zoning



- The choice of zoning is decisive for the PSHA
- Only a subset of faults (activity criteria) => limited influence for  $T = 475$  yrs

# Hypothesis on activity parameters

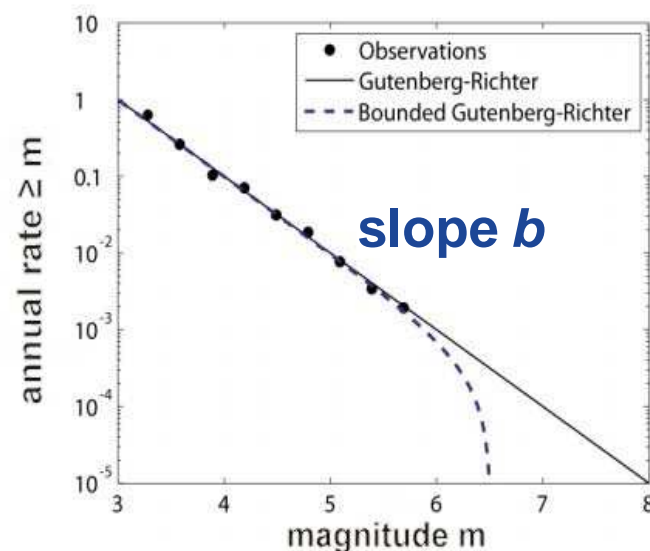
In each source zone, SHARE developed a Gutenberg-Richter curve, based on the SHEEC earthquake catalog (years 1000-2007)

❖ Stucchi *et al.* (2013) ; Grünthal *et al.* (2013)



Seismic activity characterised by *a* and *b*:

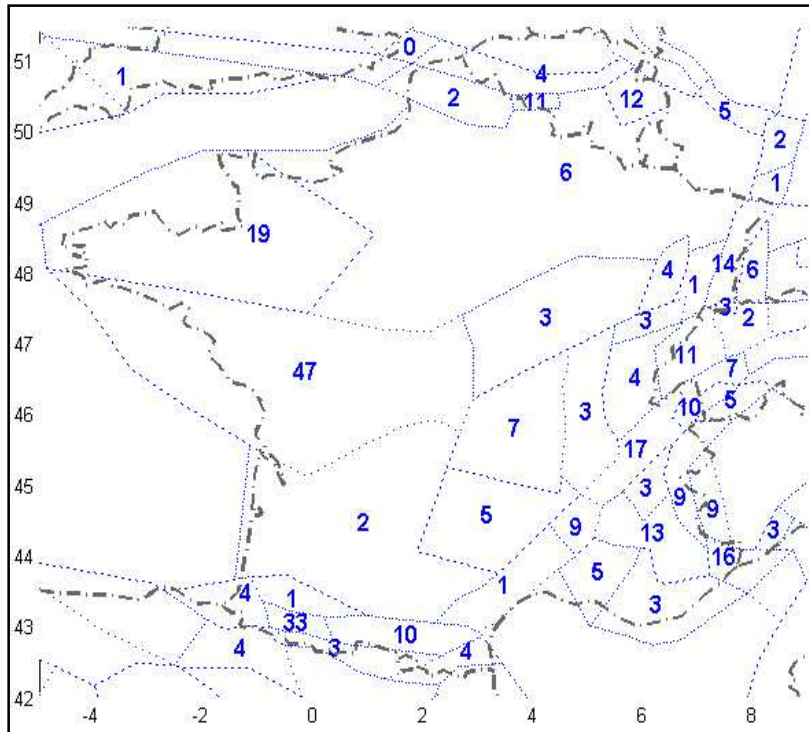
$$\text{Log } N(m) = a - bm$$



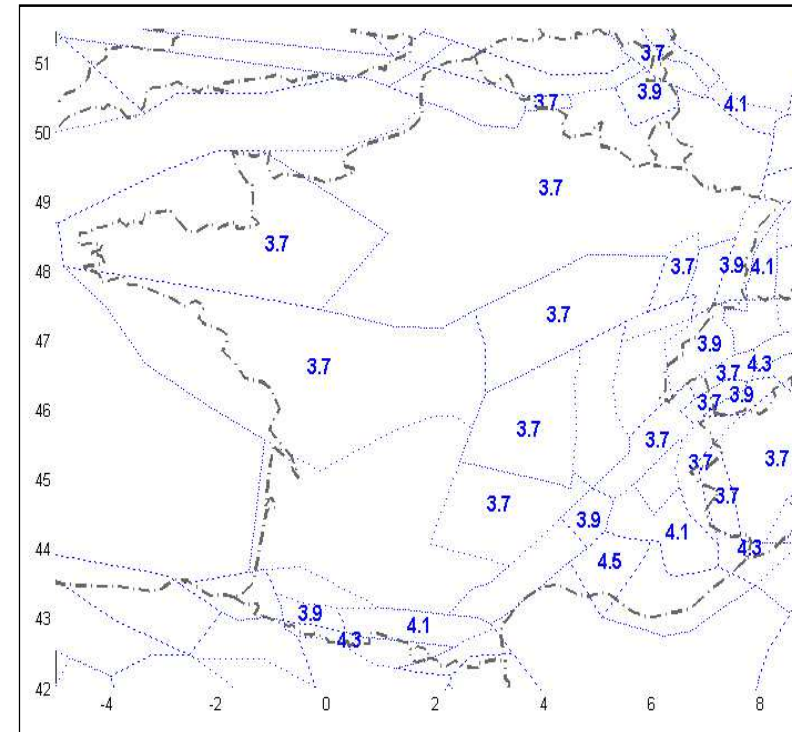
Higher b-values indicate more small events relative to large events.

# Hypothesis on activity parameters

Number of events used to derive G-R parameters



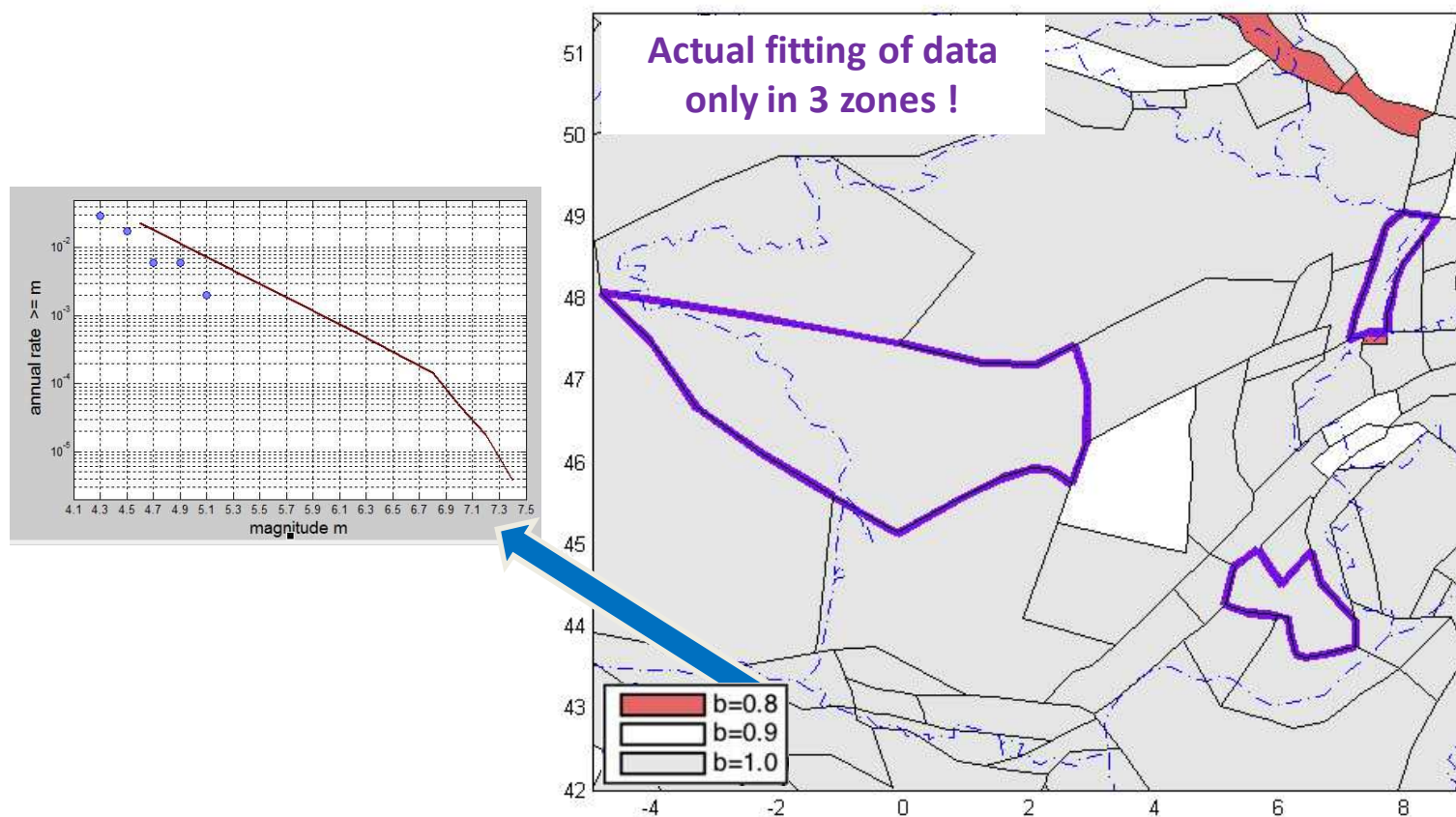
Few data because the quite high  $M_{\min}$  of completeness



As a result, most of the  $a$ ,  $b$ -values have been fixed (expert opinion) and may be questioned



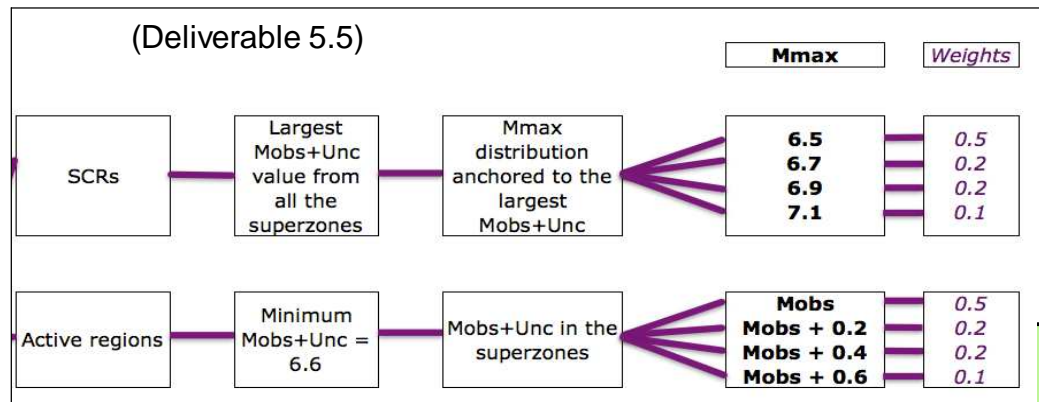
# Hypothesis on activity parameters



As a result, the uncertainty related to the recurrence parameters is not propagated.

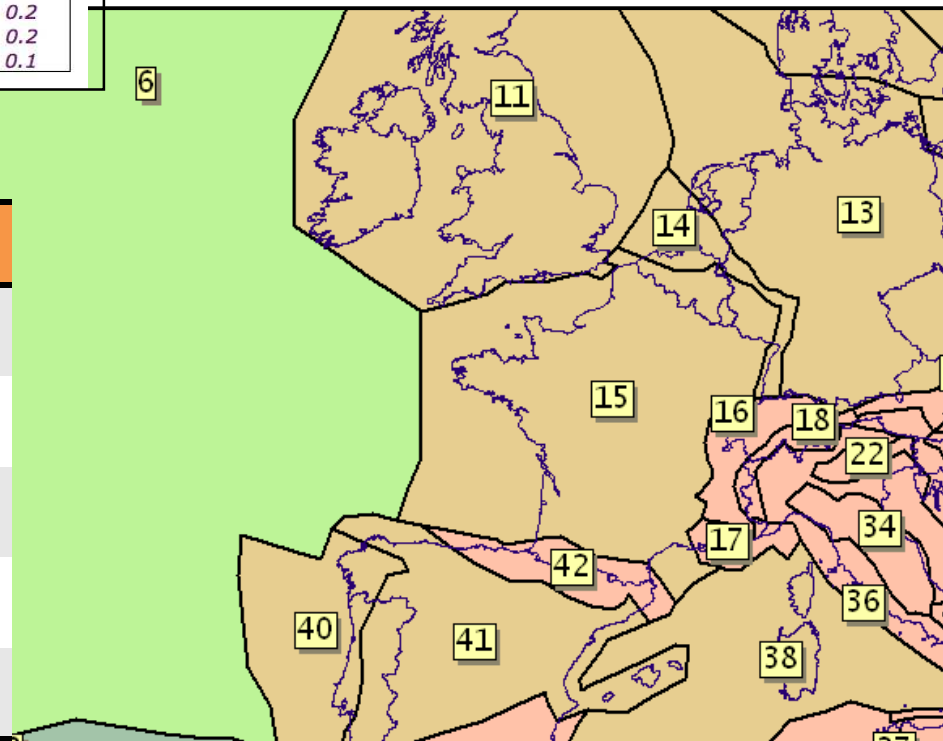
# Hypothesis on $M_{max}$

- $M_{max}$  = maximum magnitude that may occur in a region



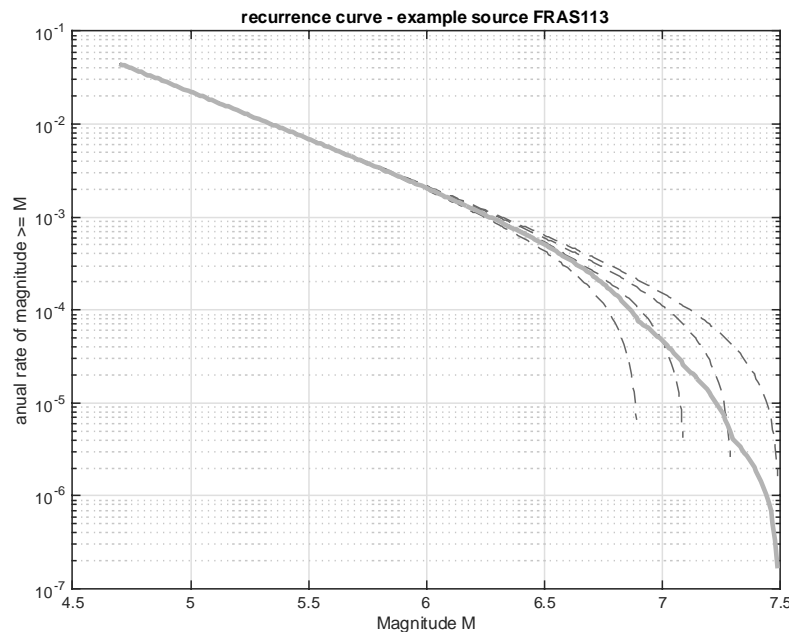
"superzones"

superzone	$M_{max}$	Observed $M_{max}$
15	6.5, 6.7, 6.9, 7.1	earthquake 12/5/1682 <b><math>M=6.2 \pm 0.3</math></b>
14	6.5, 6.7, 6.9, 7.1	earthquake 18/9/1692 <b><math>M=5.8 \pm 0.3</math></b>
42	6.8, 7.0, 7.2, 7.4	earthquake 21/6/1660 <b><math>M=6.4 \pm 0.35</math></b>
16	6.9, 7.1, 7.3, 7.5	earthquake 18/10/1356 <b><math>M=6.5 \pm 0.43</math></b>
17	6.9, 7.1, 7.3, 7.5	earthquake 23/2/1887 <b><math>M=6.6 \pm 0.3</math></b>



# Treatment of uncertainty on $M_{\max}$

- Instead of a node in the logic tree, a mean recurrence curve was applied, (weighted combination of the 4 recurrence curves)



$M_{\max}$	weight
6.9	0.5
7.1	0.2
7.3	0.2
7.5	0.1



As a result, the uncertainty related to the  $M_{\max}$  is not propagated.

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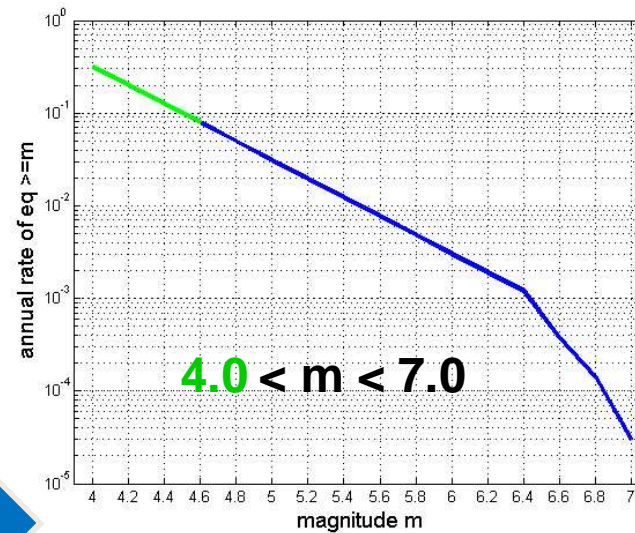
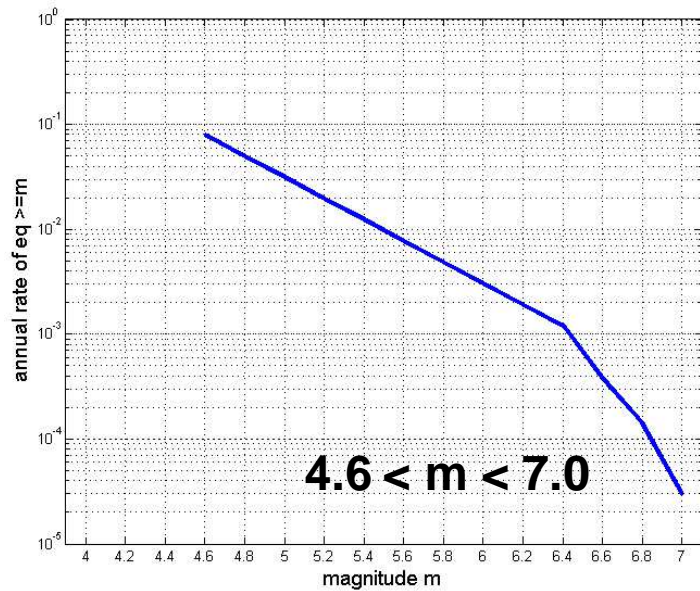
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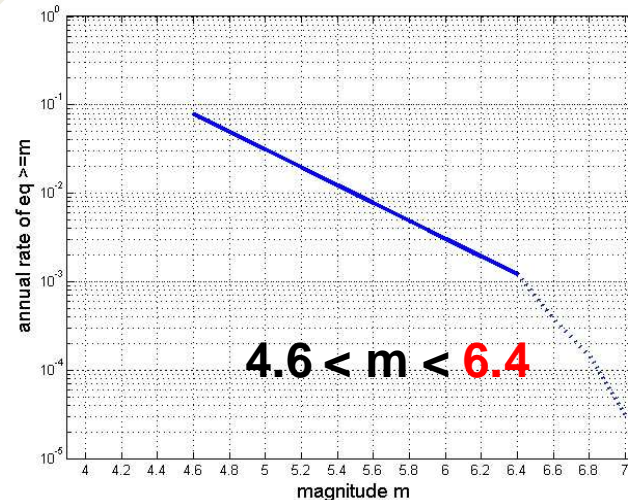
- On  $M_{\max}$  and  $M_{\min}$
- Uncertainty on earthquake recurrence

# Sensitivity on $M_{\min}$ and $M_{\max}$



Uncertainty on  $M_{\min}$

$M_{\min} = 4.0$  instead of 4.6  
Include the contribution of lower magnitudes



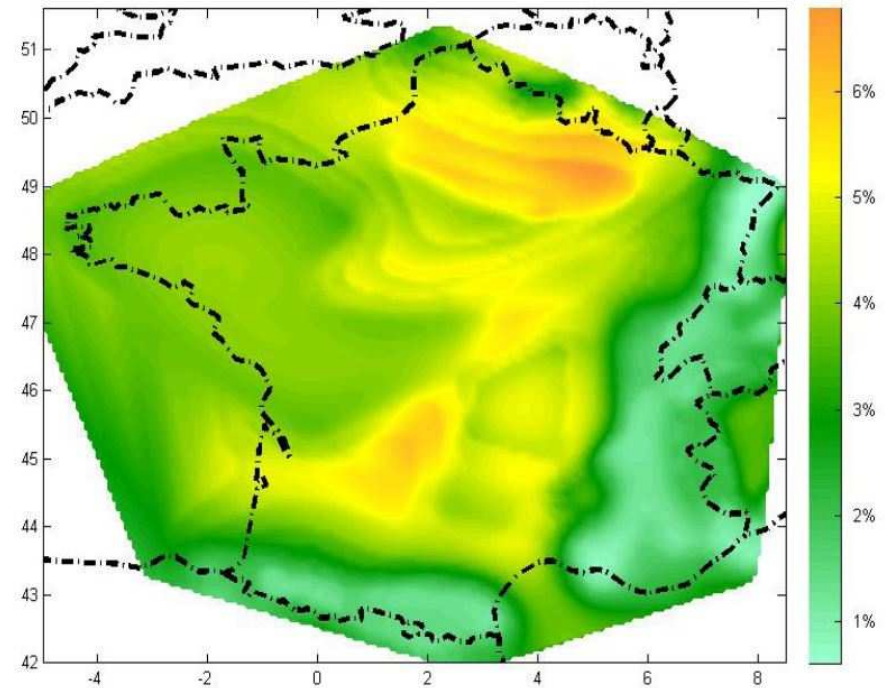
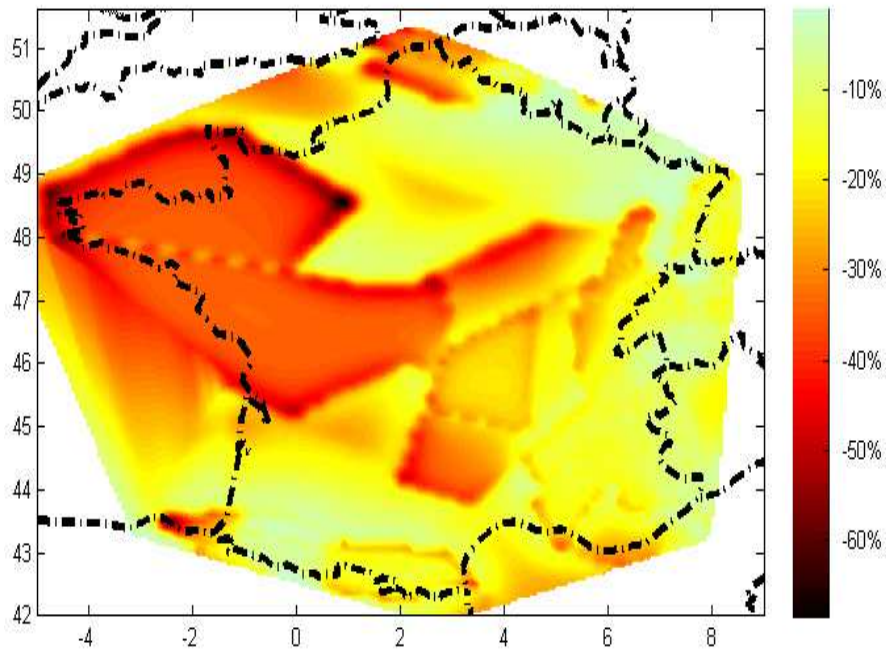
Uncertainty on  $M_{\max}$

We decrease the  $M_{\max}$  by 0.6

# Sensitivity on $M_{\min}$ and $M_{\max}$ $\frac{a_{\text{SHARE}} - a_{\text{test}}}{a_{\text{SHARE}}}$

$M_{\min}$  reduced by 0.6

$M_{\max}$  reduced by 0.6



**Impact up to -50%.  
Increase > 0.02g in a significant portion of  
France. Max increase is 0.035g**

**Impact up to 7%.  
Max decrease is 0.006g**

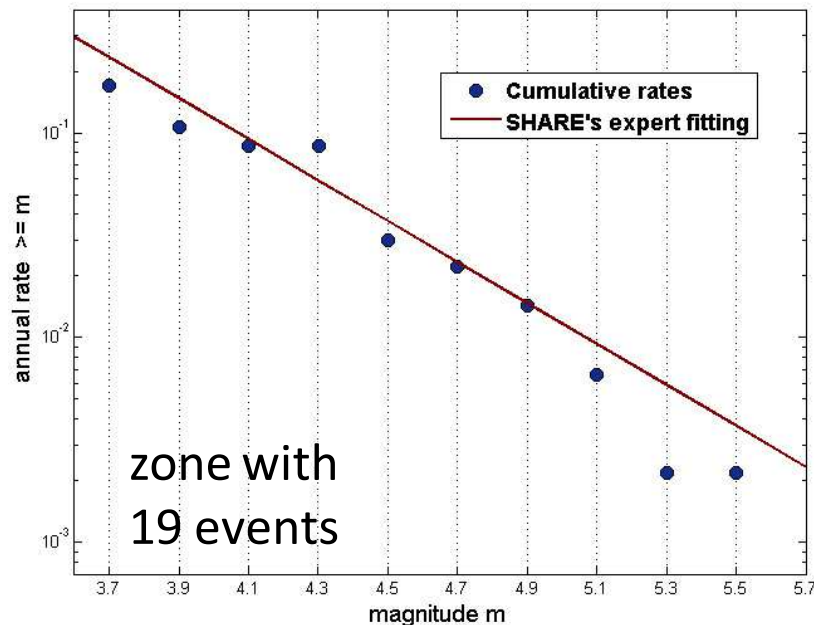
# Sensitivity on $M_{\min}$ and $M_{\max}$

- Even for return period = 4975 yrs, the underestimation of hazard, when reducing  $M_{\max}$  by 0.6, never exceeds  $0.05g$ , neither for PGA nor for  $SA(1s)$ .
- **Although generally the  $M_{\max}$  draws more attention than the  $M_{\min}$ , it seems that for France the choice of  $M_{\min}$  is more crucial than the choice of  $M_{\max}$ , for return periods < 5000 yrs and low spectral periods ( $T < 0.3s$ ).**

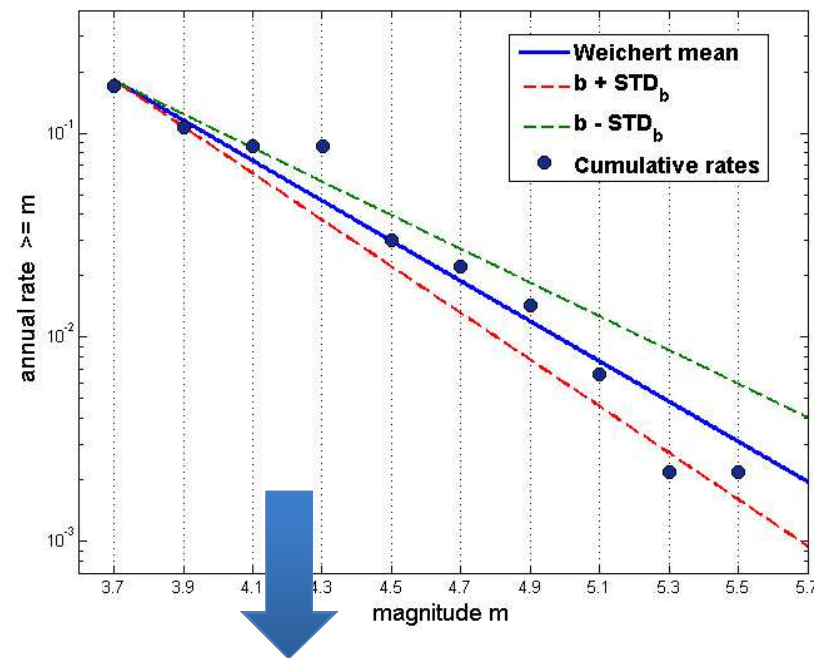
# Alternative EQ recurrence modeling

- Go back to the original SHARE earthquake catalog (=SHEEC) and derive recurrence parameters with associated uncertainties

SHARE expert fitting



Weichert,  $b=0.98$ ,  $STD_b=0.16$

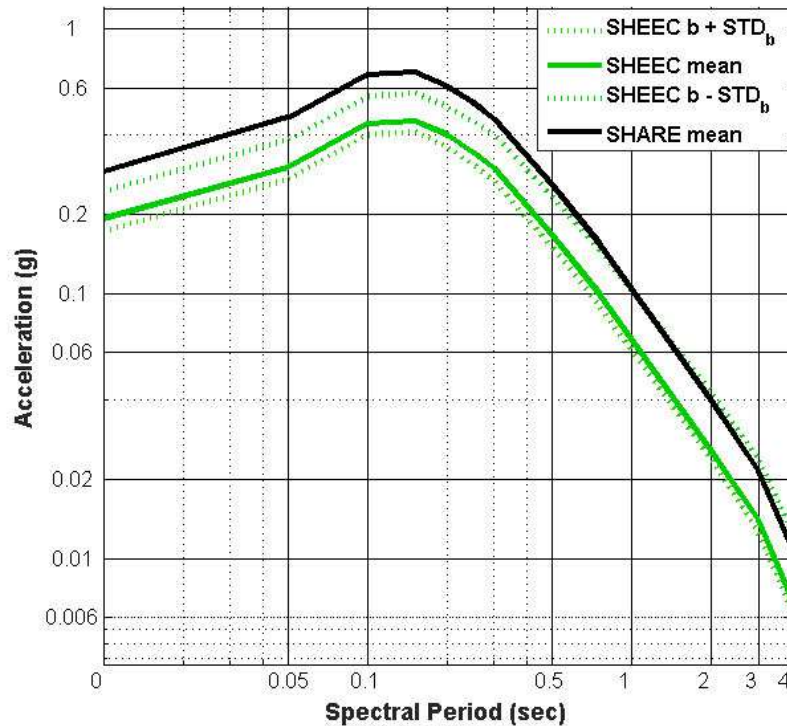


Two recurrence models are defined: a upper and lower bound.  
The seismic hazard can now be provided with associated uncertainties.

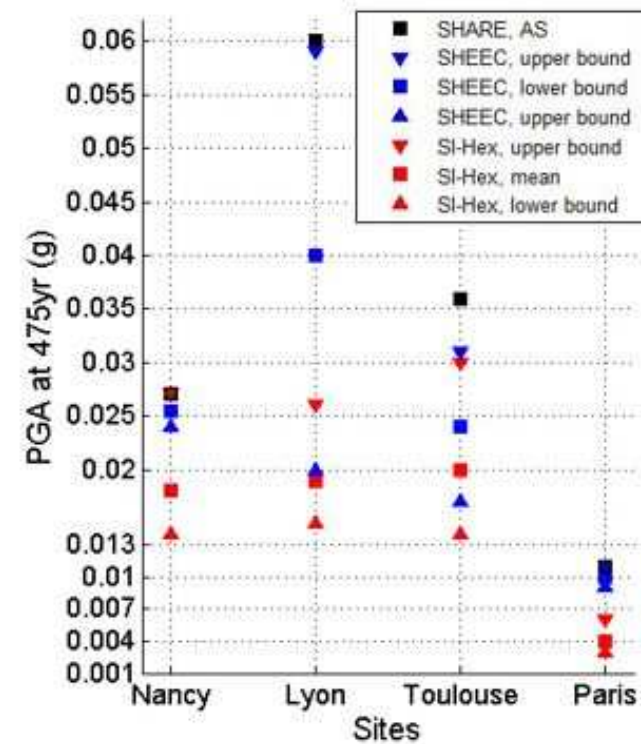


# Uncertainty on EQ recurrence

Lourdes UHS 475 yrs



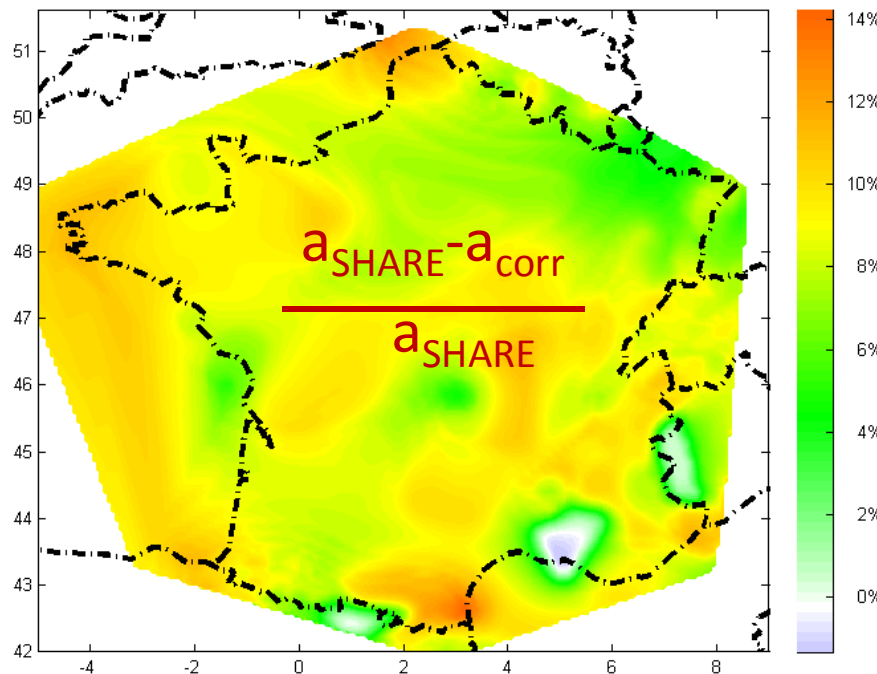
PGA 475 yrs for 4 cities



The upper and lower bounds highlight the variability of the results (up to 50%), specifically in regions of low seismicity where data can very scarce.

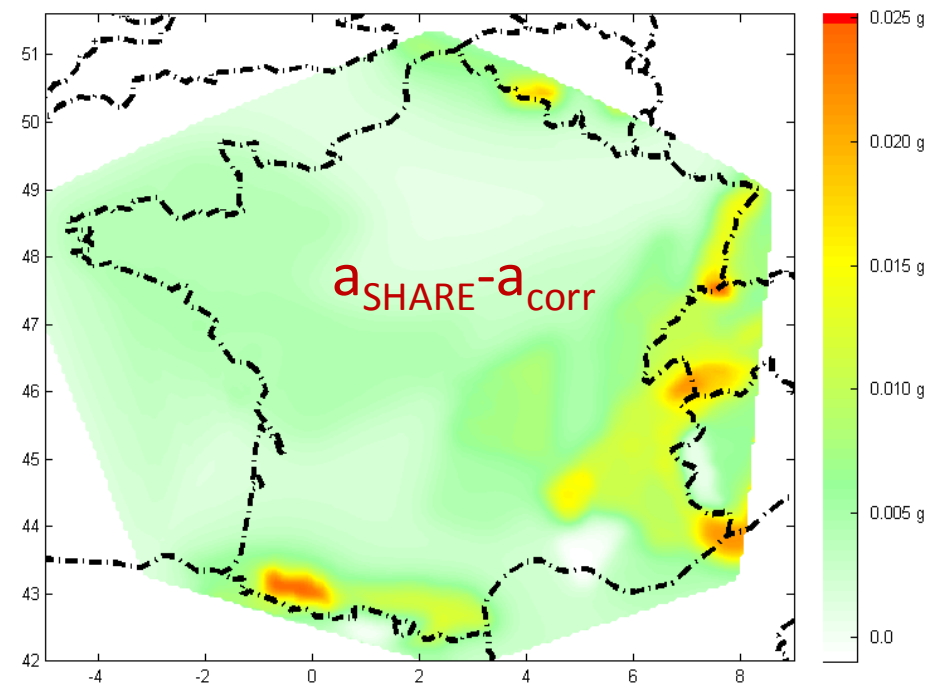
# Several SHARE input errors

Normalized difference



The corrected results lead to lower hazard by around 10%

Absolute difference



Max decrease < 0.025g

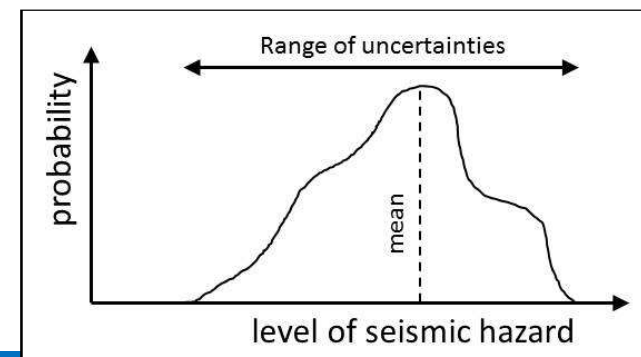
# Main conclusions

## ■ Analysis of SHARE source model:

- Inconsistencies in SHARE's input files lead to 10% larger  $PGA_{475}$  for France
- SHARE's catalog provides too few data to derive G-R parameters
- SHARE's earthquake recurrence model strongly relies on expert opinion

## ■ Impact on hazard of uncertainties related to the source model for France (PGA, 475yr):

- taking into account the uncertainty on  $b$ -value: up to 50%
- magnitude  $M_{min}$ : up to 50%
- magnitude  $M_{max}$ : up to 7%



**The uncertainties on the seismic source model should ALWAYS be quantified and their impact on the hazard should be estimated.**

THANK YOU FOR  
YOUR ATTENTION

